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DIMENSIONS OF INFORMATION PROCESSING SPEED

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This paper reviews three studies conducted as part of the Learning Abilities Measurement Program (Project LAMP). The three studies applied different methods to address the issue of the dimensionality of information processing speed. The first study applied a whole-task analysis procedure in which 508 basic trainees were administered, on a microcomputer, a broad variety of cognitive tasks. Latency and error data from those tasks were analyzed with an exploratory factor analysis of the intercorrelation matrix. The results indicated that verbal-speed, verbal-accuracy, quantitative-speed, quantitative-accuracy, reasoning-speed, and reasoning-accuracy factors could be identified. Additionally, separate general-speed and general-accuracy factors could be identified at the second order. The second study applied a stage-analysis approach to determine individual parameter estimates of encoding, comparison, decision, and response execution times. In this study, 178 basic trainees were administered a series of embedded tasks constructed to isolate processing stages on the semantic comparison task. Data were analyzed by both the simple subtraction model and the part correlation model. In both cases, the results indicated a factorial separation of processing stages with both content and process factors emerging. The third study applied a coding-analysis method to a series of matching tasks in which the nature of the matching rule was systematically altered from physical to semantic identity judgments. In this

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study, 710 basic trainees were administered the matching tasks along with simple and choice reaction time tasks. A multidimensional scaling analysis of task intercorrelations showed that the tasks could be arrayed along two orthogonal simplexes; one ordered tasks on the degree to which perceptual processing was required, the second on the depth of memory search required. Results of all three studies are discussed in terms of practical and theoretical importance.

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DIMENSIONS OF INFORMATION PROCESSING SPEED

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Paper presented at the 92nd Annual Convention of the American Psychological Association, Toronto, Ontario, Canada, 24-28 August 1984.

SUMMARY

Computerized assessment promises to yield scores that indicate how quickly individuals think, solve problems, make decisions, or more generally, process information. There is a question, however, of how many processing speed scores are necessary to adequately characterize an individual's capabilities. One possibility is that some people think faster than others on all kinds of tasks. An alternative is that some are faster than others on certain tasks but slower on different tasks. The purpose of this effort was to review three studies conducted as part of the Learning Abilities Measurement Program (Project LAMP) that collected data pertaining to this general issue of the dimensionality of processing speed. In three separate studies, large groups of Air Force basic trainees (N = 508, 178, 710, respectively) were administered a wide variety of computerized tasks designed to tap verbal, quantitative, reasoning, decision, classification and choice skills. Various multivariate analysis techniques were applied to the response time data from these tasks in order to determine whether a single speed factor could account for subject-to-subject variability or whether multiple speed factors were required. In the first study, the data could roughly be accounted for by a general speed factor, but a much better account could be made if separate reasoning speed, verbal speed, and quantitative speed factors were posited. Similarly, in the second and third studies, a general speed factor was found, but the data could be more easily accommodated by positing additional factors, such as perceptual processing speed and memory search speed. These studies represent an important first step in determining the number and nature of information processing speed factors. Further basic research is necessary to develop a theory-based taxonomy of information processing speed variables before assessment applications can be pursued systematically. Nevertheless, exploratory application efforts might benefit from a consideration of the kinds of processing speed dimensions discussed in this paper.

PREFACE

This technical paper, based on a symposium presentation at the 92nd Annual Convention of the American Psychological Association, Toronto, Ontario, Canada, 24-28 August 1984, documents several projects accomplished for the Air Force Learning Abilities Measurement Program (Project LAMP). The objectives of the program are to explore the feasibility of a model-based system of psychological assessement.

The research reported herein was conducted at the Manpower and Personnel Division of the Air Force Human Resources Laboratory (AFHRL) and was sponsored by the Air Force Office of Scientific Research. Data were collected at the AFHRL experimental testing facility at Lackland AFB.

This paper reports results from studies conducted in collaboration with Dr. Raymond Christal and Dr. Bill Tirre, of AFHRL, who also deserve mention for their comments on this manuscript. The AFHRL staff at Lackland AFB, especially Major Hector Acosta, Dick Nicewonger, and Refugio Gonzalez provided significant assistance in all aspects of the data collection. From the OAO Corporation, Richard Walker, Frank Rilling, Janice Hereford, Jenny Hutchings, and Ernest Pena provided important help in creating task software and analyzing the data.

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DIMENSIONS OF INFORMATION PROCESSING SPEED

I. INTRODUCTION

The last few years have seen a revival of interest in the idea that general information processing speed is related to intelligence. Some empirical evidence indicates that a single information processing speed factor is related to learning ability in certain contexts. For example, memory retrieval speed differentiates those who learn quickly while reading from those who do not, and general reaction time differentiates those who efficiently transfer new information to permanent memory storage from those who are less efficient with this process. However, little research has addressed the question of whether information processing speed is a single, general factor or whether there are different varieties of processing speed. Three recent studies under the Learning Abilities Measurement Program (Project LAMP) have provided converging evidence for multiple speed factors, using three distinct approaches.

The first approach, whole-task analysis, is the traditional methodology of differential psychology in which examinees are administered a battery of various cognitive tasks, and factor analysis is applied to the matrix of correlations among performance indicators on those tasks to derive a small set of factors that account for the correlations. The second approach, stage analysis, is the analysis of sequences of information processing stage with the goal being to determine which stage serves as the locus of individual difference variation in overall task proficiency. The third approach, coding analysis, is also an information processing approach, but differs from the second in being concerned less with qualitatively distinct processing stages than with how various kinds of information in memory are accessed (Slide 1).

II. STUDY I

In the first study (based on data from Kyllonen, Christal, & Tirre, 1984), using a microcomputer, 508 Air Force basic trainees were administered a broad variety of cognitive tasks that were designed to tap verbal (V), quantitative (N1, N2), inductive reasoning (I), deductive reasoning (D), and memory span (M) abilities. Slide 2 shows some example items. Factor, cluster, and multi-dimensional scaling analyses of latency and error data yielded separate verbal, quantitative, and reasoning accuracy factors and also separate verbal, quantitative, and reasoning speed factors.

Table 1 and Slides 3 and 4 show the results of the exploratory factor analysis of the full intercorrelation matrix with oblique rotation of the factor axes. Both the Kaiser-Guttman criterion and the Screen test indicated an eight-factor solution. The factors were interpreted as Reasoning Level (R_l), Reasoning Speed (R_s), Verbal/Declarative Knowledge Level (V_l), Verbal Retrieval Speed (V_s), Numerical Level (N_l), Numerical/Computation Speed (N_s), Technical Knowledge (TK), and Clerical Speed (CS).

The Reasoning Level factor (R_l) was loaded by the percent correct (PC) scores from tests in the Inductive Reasoning, Deductive Reasoning, and Memory categories; all tests in these categories loaded highest on this factor.

The Reasoning Speed factor (R_s) was loaded by the latency scores from these same tests, and with the exception of three verbal content tests which split their variance between the Rs and Vs factors, all loaded highest on the R_s factor.

SLIDE 1

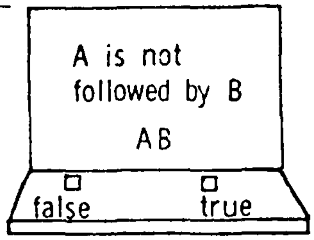
DIMENSIONS OF PROCESSING SPEED

- WHOLE-TASK ANALYSIS
  - Speed-level independence?
  - Are there speed factors (reasoning, verbal, number speed)?
- STAGE ANALYSIS
  - Identify elementary operations with embedded tasks
  - Are processing stages factorially identifiable & independent?
  - Processing speed-aptitude relations
  - Process-content distinctions
- CODING ANALYSIS
  - Vary the decision rule for judging similarity using the same task (matching task)
    - physical identity
    - name identity
    - category identity
    - meaning identity (synonyms)
  - One factor or multi-factor? (or simplex?)
  - Which underlie intelligence?
  - Which underlie learning efficiency?

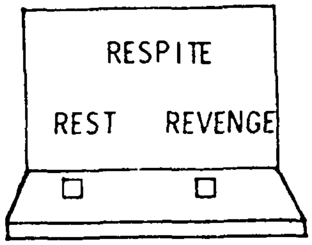
EXAMPLE TEST ITEMS (Study 1)

TEST NAME | **ITEM**

SENTENCE-PICTURE VERIFICATION
(Reasoning)



SYNONYMS
(Verbal)



SYMBOLIC ARITHMETIC
(Numerical)

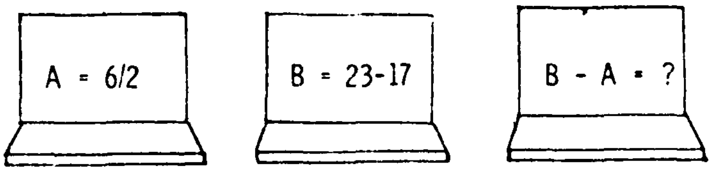


Table 1. Oblique Rotated Factor Pattern Matrix Study 1 (N = 508)

Hypothesized Factor	Test Name	R_1	R_s	V_1	V_s	N_1	N_s	TK	CS	h^2
COMPUTERIZED TESTS										
I	Remote analogies (PC)	.37		.30						.50
I	Number sets (PC)	.43								.49
I	Letter sets (PC)	.48								.45
D	3-term series (PC)	.50								.35
D	Sentence-picture ab (PC)	.40		.26						.48
D	Trait levels (PC)	.43								.37
M	Paired associates (PC)	.34								.46
M	Memory span (PC)	.40								.29
I	Remote analogies (L)		.40		.40					.51
I	Number sets (L)		.58							.44
I	Letter sets (L)		.62							.58
D	3-term series (L)		.62							.46
D	Sentence-picture ab (L)		.22		.21					.25
D	Trait levels (L)		.38							.20
M	Paired associates (L)		.40		.40					.56
M	Memory span (L)		.31							.30
V	Fact verification (PC)			.43						.24
V	Synonym recognition (PC)			.96						.84
V	Fact verification (L)			-.29	.47					.62
V	Synonym recognition (L)				.78					.79
N_1	Number facts (PC)					.33				.13
N_1	Arithmetic tracking (PC)					.68				.49
N_1	Simple symbolic (PC) arithmetic					.62				.51
N_2	Complex symbolic (PC) arithmetic	.47				.28				.54
N_2	Sun-Tue addition (PC)	.25				.45				.36
N_1	Number facts (L)				.29		.74			.79
N_1	Arithmetic tracking (L)						.67			.64
N_1	Simple symbolic (L) arithmetic						.77			.75
N_2	Complex symbolic (L) arithmetic		.45				.43			.61
N_2	Sun-Tue addition (L)						.38			.39
ASVAB TESTS										
Q	Arithmetic Reasoning	.38					.33	.30		.64
Q	Mathematics Knowledge	.32					.36	.27		.62
V	Word Knowledge			.79						.74
V	Paragraph Comprehension			.42						.42
V	General Science			.52				.44		.61
TK	Auto-Shop Information							.77		.56
TK	Mechanical Comprehension	.27						.74		.70
TK	Electronics Information							.76		.63
CS	Coding Speed								.74	.61
CS	Numerical Operations								.79	.63

Note. Loadings < .25 are omitted except for Sentence-picture ab in which two highest loadings are included; matrix reflected for positive manifold. In parentheses following computerized test name L indicates latency score, PC indicates percent correct score. Factor names are as follows: R_1=Reasoning Level, R_s=Reasoning Speed, V_1=Verbal Level, V_s=Verbal Speed, N_1=Numerical Level, N_s=Numerical Speed, TK=Technical Knowledge, CS=Clerical Speed, h^2=Commonality.

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SUMMARY

- WHOLE TASK ANALYSIS
  - General level factor is clearly separate from general speed factor
  - Separable speed factors found in Reasoning, Verbal, and Number domains
  - Gaps and mixtures in ASVAB
- STAGE ANALYSIS
  - Processing stages can be identified with factor analysis
  - MDS arrays tasks along two simplex dimensions
    - number of processes
    - differential content
- CODING ANALYSIS
  - Matching tasks (PI, NI, CI, MI) arranged in 2 orthogonal simplexes
    - degree of perceptual processing
    - depth of search/code strength

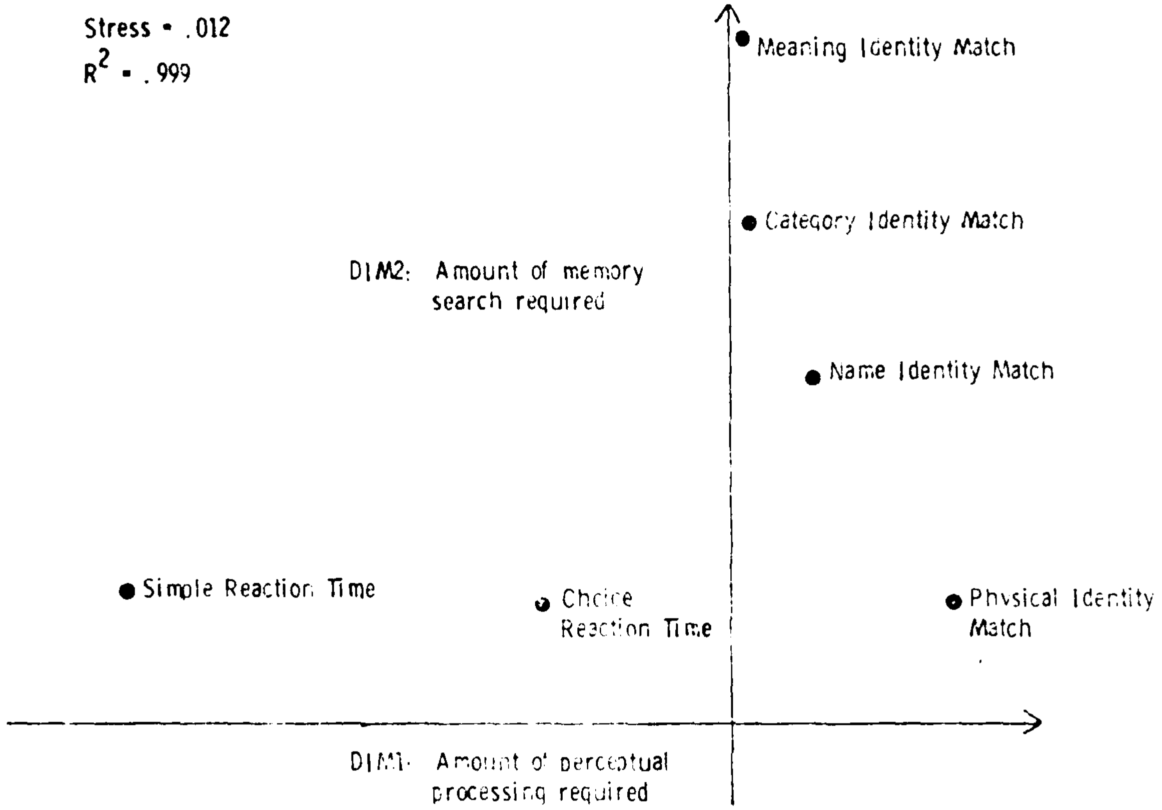
SLIDE 12

IMPLICATIONS FOR APTITUDE TESTING

- There is more than one processing speed parameter
- Processing speed cannot be measured independent of content
  - general content: verbal, symbolic, number (space?)
  - specific content: e.g., word valence vs. letter category
- Processing speed depends on qualitative nature of process
  - perceptual analysis
  - memory search
- MDS of R matrix reveals subtle relationships
  - important first step toward precise characterization

SLIDE 11

MDS SOLUTION (2 DIM)



Slide 11 shows that tasks could be arrayed along two simplexes. Dimension 1 orders tasks by the amount of perceptual processing (i.e., physical feature analysis required), from simple reaction time to physical identity matching. Dimension 2 orders tasks by the [illegible] of memory search required, from physical identity to meaning identity matching. It is interesting to note that the simple reaction, choice reaction, and physical identity matching tasks have projections to the same point on Dimension 2, indicating that all these tasks involve the same minimal amount of memory search. Also interesting is that the projection of the physical identity matching task on Dimension 1 suggests that the perceptual processing demands of this task exceed those of the other identity matching task, which of course is consistent with an intuitive analysis of the demands of the task.

V. CONCLUSIONS

Three diverse analysis paradigms applied to data from three diverse sets of cognitive tasks provided converging evidence that information processing speed is multidimensional (Slides 12 and 13).

Using a whole task analysis approach, it was shown that a general level factor could be clearly separated from a general speed factor, but more importantly, that separate reasoning, verbal, and computation speed factors could be identified. An incidental benefit from this analysis was that limitations to the current ASVAB were suggested.

Applying a stage analysis approach to a second data set, it was shown that process and content orderings of cognitive tasks could be produced with a combination of factor analysis and multidimensional scaling.

Applying a coding analysis approach to a third data set revealed an interesting structural relationship among the kinds of matching tasks that have received a great deal of attention over the last decade. A multidimensional scaling of the intercorrelations of task latencies yielded a solution in which tasks were arrayed along two orthogonal simplexes. The first arrayed tasks by the degree to which perceptual analysis was required. The second arrayed tasks by the depth of memory search required to perform item comparisons.

The theoretical importance of these results stems from the finding that intelligent behavior results from the interactive workings of somewhat independent processes. The applied importance is that future selection and classification systems will have to take account of the fact that more than one number will be required to represent how fast and accurately an individual processes information.

SLIDE 9

EXAMPLE ITEMS

ASSIST

HELP CUT

Reaction Time:
Respond to any light on screen

ASSIST

• CUT

Choice Reaction Time:
Respond to key under star

CUT

CUT SET

Physical Identity:
Respond to physically identical item

CUT

set cut

Letter Identity:
Respond to alternative having same letters

BEAN

KNIFE PEA

Example 1

BRICK

BOARD SKY

Example 2

Categorical Identity: Respond to alternative falling in the same category as the stem word (50 unlisted categories used)

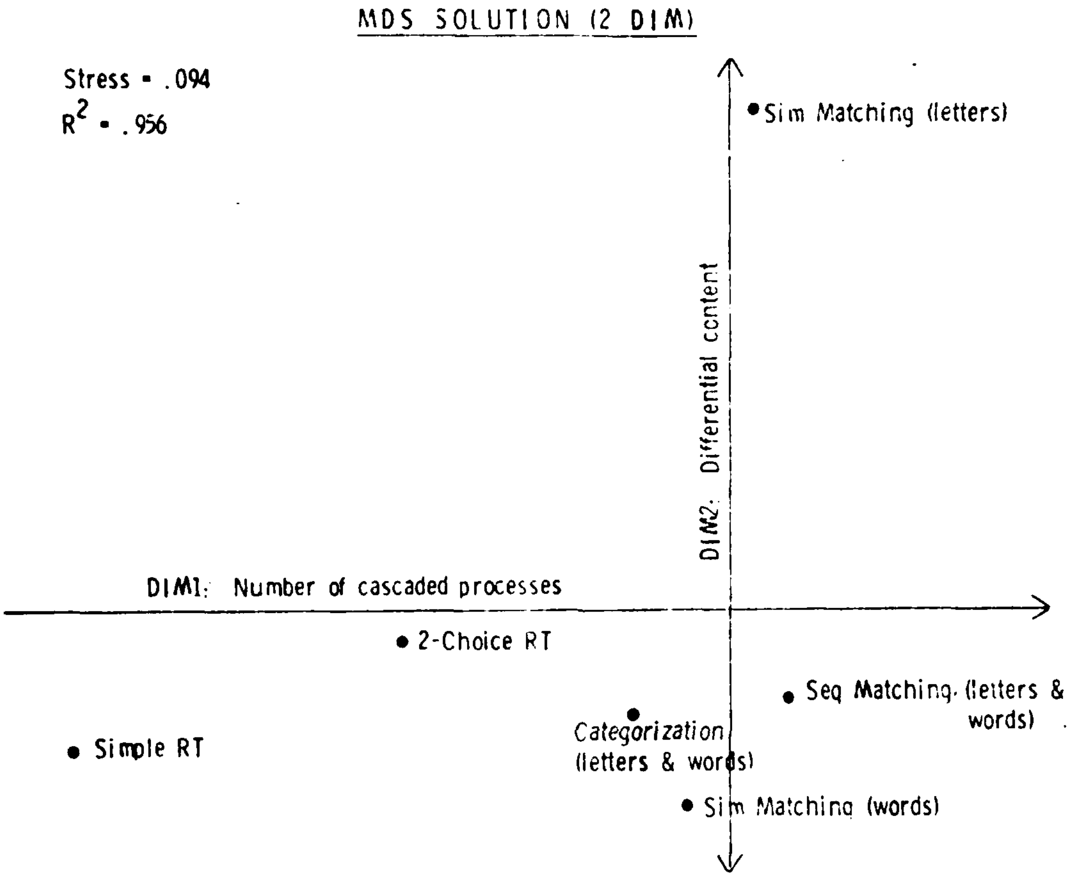
SLIDE 10

RELIABILITIES, MEANS AND INTERCORRELATIONS OF SELECTED INFORMATION PROCESSING TASKS

TASK	r_{11}	MEAN RESPONSE LATENCY	SD	INTERCORRELATIONS RT	CRT	PI	NI	CI	MI
Simple Reaction Time	.98	.276	.059	•					
2-Choice Reaction Time	.98	.404	.064	38	•				
Physical Identity	.99	.655	.125	22	41	•			
Name Identity	.98	.722	.093	28	52	60	•		
Category Identity	.98	1.139	.222	27	45	49	72	•	
Meaning Identity	.98	1.695	.428	19	34	36	56	75	•

N • 710

SLIDE 8


MDS SOLUTION (2 DIM)
Stress = .094
R² = .956
Sim Matching (letters)
DIM2: Differential content
DIM1: Number of cascaded processes
2-Choice RT
Seq Matching (letters & words)
Categorization (letters & words)
Simple RT
Sim Matching (words)

SLIDE 6

DIMENSIONS OF INFORMATION PROCESSING SPEED

TASK		F_1 RT	F_2 CRT	F_3 CAT	F_4 SEQ MAT	F_5 SIM MAT/W	F_6 SIM MAT/L
RT:	LH	76					
	RH	92					
CRT:	"L""D"		75				
	"even""odd"		94				
	"pos""neg"		93				
	"vowel""consonant"		78				
CAT:	words (W)			64			
	letters (L)			87			
SEQ MAT:	W (1)				72		
	W (2)				80		
	L (1)				100		
	L (2)				81		
SIM MAT:	W (1)					85	
	W (2)					87	
	L (1)						71
	L (2)						54

SLIDE 7

FACTOR INTERCORRELATIONS

	F_1 RT	F_2 CRT	F_3 CAT	F_4 SEQ MAT	F_5 SIM MAT/W	F_6 SIM MAT/L
F_1 RT	---					
F_2 CRT	61	---				
F_3 CAT	42	62	---			
F_4 SEQ MAT	31	57	65	---		
F_5 SIM MAT/W	34	63	57	63	---	
F_6 SIM MAT/L	08	42	39	42	33	---

NOTE: Loadings $< .25$ omitted
Log time, correct items only, error feedback condition

Table 3. Factor Pattern Matrix of Latency Scores from Reaction Time Tasks: Study 2 (N = 178)

	F1 RT	F2 CRT	F3 CAT	F4 SQM	F5 SMM_W	F6 SMM_I
Task						
SRT-LH	.76					
SRT-RH	.92					
CRT-LD		.75				
CRT-EO		.94				
CRT-PN		.93				
CRT-VC		.78				
CAT-W			.64			
CAT-L			.87			
SQM-W1				.72		
SQM-W2				.80		
SQM-L1				1.00		
SQM-L2				.81		
SMM-W1					.85	
SMM-W2					.87	
SMM-L1						.71
SMM-L2						.54
Factor						
F1-RT	---					
F2-CRT	.61	---				
F3-CAT	.42	.62	---			
F4-SQM	.31	.57	.65	---		
F5-SMM_W	.34	.63	.57	.63	---	
F6-SMM_I	.08	.42	.37	.42	.33	---

Note. Oblique solution with log latency; bottom half of table is factor intercorrelations; loadings less than .25 omitted.

A match was made on the basis of either physical, name, category, or meaning identity. Slide 10 shows the reliabilities, means, standard deviations, and intercorrelations of tasks. As is typically the case with reaction time tasks, reliabilities were uniformly high. Response latency also increased as a function of the depth of memory search from physical identity (PI) judgements, involving minimal memory search (because patterns could be compared solely on the basis of the physical code), to meaning identity (MI) judgements involving considerable memory search (presumably because word meanings can be compared only after retrieval of considerable semantic feature sets for each of the to-be-compared words). Although not shown, stimuli for all tasks were selected such that percent correct scores all exceeded 90. The matrix in Slide 9 suggests a simplex pattern but a multidimensional scaling (again using ALSCAL) of the data yielded a more easily interpretable two dimensional solution.

Table 2. List of Tests and Processing Components: Study 2 (N = 178)

Tests	Test Label	Processing Component			
		Respond	Decide	Encode	Compare
Simple Reaction Time	(SRT)				
Left Hand	(SRT-LH)	X			
Right Hand	(SRT-RH)	X			
Choice Reaction Time	(CRT)				
"L" vs. "D"	(CRT-LD)	X	X		
"even" vs. "odd"	(CRT-EO)	X	X		
"positive" vs. "negative"	(CRT-PN)	X	X		
"vowel" vs. "consonant"	(CRT-VC)	X	X		
Categorization	(CAT)				
Words	(CAT-W)	X	X	X	
Letters	(CAT-L)	X	X	X	
Sequential Matching	(SQM)				
Words (Block 1)	($SQM-W_1$)	X	X	X	X
Words (Block 2)	($SQM-W_2$)	X	X	X	X
Letters (Block 1)	($SQM-L_1$)	X	X	X	X
Letters (Block 2)	($SQM-L_2$)	X	X	X	X
Simultaneous Matching	(SMM)				
Words (Block 1)	($SMM-W_1$)	X	X	2	X
Words (Block 2)	($SMM-W_2$)	X	X	2	X
Letters (Block 1)	($SMM-L_1$)	X	X	2	X
Letters (Block 2)	($SMM-L_2$)	X	X	2	X

Note. "X" means the column component was required for the particular row test; "2" means the component had to be executed twice.

Number of processes involved, from Simple Reaction Time to Semantic Matching (although with a slight misordering on the simultaneous versus sequential versions of the matching tasks). On the second dimension, tasks are separated by content (word valences versus letter attributes). Toward the top of the axis is the letter content, toward the bottom is the word content, and between is the mixture (contents were mixed on the first four factors). The key point to be drawn from these analyses is that although there is evidence for a general speed factor (observe the positive manifold in the factor intercorrelation matrix), there is also considerable evidence for more specific speed factors arrayed by both process and content.

IV. STUDY 3

In the third study (based on data from Kyllonen, Tirre, & Christal, 1984), a standard matching paradigm was used in a coding analysis approach to examine differential facility in accessing various memory codes. A series of cognitive tasks were administered to 710 basic trainees. In addition to the simple and choice reaction tasks used in the previous study, the trainees were administered a series of tasks that varied as to match decision rule (Slide 9).

SLIDE 5

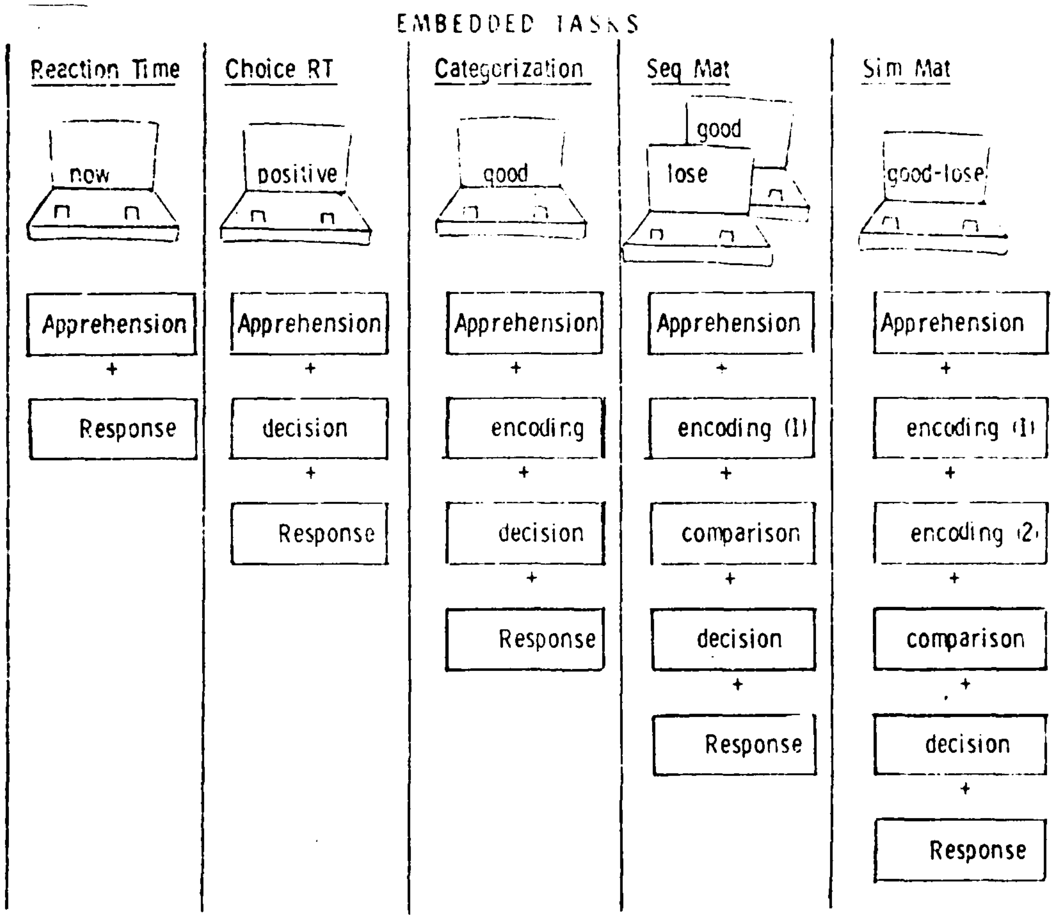


Table 3 and Slide 6 show the results of an oblique factor analysis of the latency data (log latency for correct items only), in which the factor retention and rotation criteria were the same as in the previously discussed study. The top half of Table 3 and Slide 7 show the factor loadings for the reaction time tests and the bottom half of Table 3 and Slide 7 show the factor intercorrelations. Note that the first four factors are arrayed as process-ensembles corresponding to the process requirements in Table 2. But factors 5 and 6 split according to content; that is, according to the nature of the material to be encoded (word valences [W] versus letter categories [L]).

It is apparent that the factors are all fairly highly intercorrelated. This analysis gives less evidence of complete process independence than did the subtraction analysis but is ambiguous on the issue of whether individual differences variation is due to process or content differences. In the case of the simultaneous matching task (SMM), there is reliable individual differences variance due to content, but not entirely independent of process since $\underline{r}$ [F5, F6] = .33. Thus, a series of analyses of the factor intercorrelation matrix were performed in an attempt to clarify the relationships among the factors.

The most readily interpretable analysis was a two-dimensional scaling solution, using ALSCAL (Young & Lewyckyj, 1979), for the six-variable matrix (Slide 8). This analysis orders the cognitive tasks along two orthogonal simplexes. On the first dimension, tasks are ordered by the

Reasoning, AR, and Mathematics Knowledge, MK) split their variance between three factors, R_1, N_s, and TK, indicating both speed and level components to these tests. The three Verbal/Declarative Knowledge tests in the ASVAB (Word Knowledge, WK, Paragraph Comprehension, PC, and General Science, GS) loaded highest on the V_1 factor, indicating that primarily these have level components. The three technical knowledge tests (Auto-Shop Information, AS, Mechanical Comprehension, MC, and Electronics Information, EI) primarily defined the TK factor, and the two speeded tests formed a separate factor (CS). Note that in terms of the factorial structure revealed in this analysis, the ASVAB fails to measure three abilities: Reasoning Speed, Verbal Speed, and Numerical Level. Further, most of the ASVAB tests are not factorially pure; that is, they measure more than one ability. Further validation studies could indicate whether this represents a practical concern in the ASVAB.

Because oblique rotation was applied to the original factor pattern matrix, the first-order factors were free to correlate and this enabled the analysis of a second-order solution. This analysis (not shown) indicated that uncorrelated ($\underline{r}$ = -.05) general speed ($\underline{g_s}$) and general level ($\underline{g_l}$) factors could be identified at the second order.

Finally, an orthogonal rotation of the original factor pattern matrix was performed using the Varimax criterion. A great deal of emphasis was not placed on this solution because it failed to achieve what Thurstone has called "simple structure." Yet, it was interesting that scores that defined separate speed factors in the oblique solution essentially collapsed into a single speed factor in the orthogonal solution. Thus, regardless of the factor rotation method, a general speed factor is defined: If orthogonal rotation is employed, the speed factor is first order; if oblique rotation is employed, the speed factor is second order.

In sum, analysis of correctness and latency scores from a broad variety of cognitive tests suggested the existence of both primary and secondary speed and level factors. This suggests that what have been known as primary mental abilities actually include separate speed and level components. The speed component of three primary abilities--reasoning, verbal, and numerical--are separable yet somewhat correlated, and thus, they form a general speed factor.

III. STUDY 2

In the second study (based on data from Kyllonen, 1984b), using a stage-analysis approach, 178 basic trainees were administered a series of cognitive tasks designed to yield individual parameter estimates of encoding, comparison, decision, and response-execution speed. This was accomplished through the use of a subtraction method: A series of tasks was created such that they could be ordered from simple to complex in terms of processing requirements (see Slide 5). The most complex of the tasks, a simultaneous semantic comparison task, required the execution of all the information processing steps, and successively simpler tasks were created by systematically eliminating one step. In this way, the parameters, which represented the duration of the various processing steps, could be estimated by taking the difference between response time (T) on each of the tasks and response time on the next simpler task ($\underline{T_n} - \underline{T_{n-1}}$). Reliabilities of the four parameters estimated in this fashion were uniformly high (all exceeded .80). But interestingly, none of the between-parameter correlations were significantly different from zero. If additivity of processing stages can be assumed in this paradigm, then the lack of significant correlation among parameters can be taken to indicate that four independent dimensions of processing speed were present in this study.

However, the additivity assumption for these kinds of tasks has been questioned (Donaldson, 1983; McClelland, 1979). Thus, an alternative analysis of dimensionality was also performed on the data. The variables are five sets of reaction time tasks listed with their processing component description in Table 2.

FACTOR PATTERN MATRIX

(cont., N = 508, Study 1)

	R_L	R_S	V_L	V_S	N_L	N_S	TK	CS
Arith Reason (AR)	+					+	+	
Math Know (MK)	+					+	+	
Word Know (WK)			+					
Para Comp (PC)			+					
Gen Science (GS)			+				+	
Auto-Shop (AS)							+	
Mech Comp (MC)	+						+	
Elec Info (EI)							+	
Code Speed (CS)								+
Num Ops (NO)								+

The Verbal/Declarative Knowledge Level Factor (V_l) was loaded by the percentage of correct scores from the Fact verification and Synonym recognition tasks, and the corresponding Verbal Retrieval Speed factor (V_s) was loaded by the speed scores from these two tests.

The Numerical Level factor (N_l) was loaded by percent correct scores of tasks from both the Simple- and Complex-Numerical categories, and the latency scores from these same tasks defined a Numerical/Computation Speed (N_s) factor.

The final two factors, Technical Knowledge (TK) and Clerical Speed (CS), were defined exclusively by the total scores from certain paper-and-pencil Armed Services Vocational Aptitude Battery (ASVAB) tests (DoD, 1984). Although it might seem surprising that the ASVAB Numerical Operations (NO) test did not load on the N_S factor, a previous analysis of this task (Kyllonen, 1984a) showed that only a small fraction (13%) of the time examinees spend on this task is devoted to actual numerical computations and only a small percentage of the total score variation on this task (20%) is due to computational facility. The remainder of the time is devoted to finding the answer and marking the answer sheet, and thus, the test measures primarily clerical not computational skills.

Although the purpose of this analysis was to determine whether speed factors could be identified, an incidental benefit (apparent from Table 1) was that the factorial composition of the ASVAB tests is suggested. The two Quantitative-Reasoning tests from the ASVAB (Arithmetic

FACTOR PATTERN MATRIX

(N = 508, Study 1)

	R_L	R_S	V_L	V_S	N_L	N_S	TK	CS
Analogies	+		+					
No. Sets	+							
Ltr Sets	+							
3-Term	+							
Sent-Pict	+		+					
Trait Levels	+							
Paired-Assoc	+							
Mem Span	+							
Analogies (L)		+		+				
No. Sets (L)		+						
Ltr Sets (L)		+						
3-Term (L)		+						
Sent-Pict (L)		+						
Trait Levels (L)		+						
Paired-Assoc (L)		+		+				
Mem Span (L)		+						
Fact Verify			+					
Synonym Match			+					
Fact Verify (L)			-	+				
Synonym Match (L)				+				
Number Facts					+			
Arith Tracking					+			
Symbol Arith I					+			
Symbol Arith II	+				+			
Sun-Tue Addition	+				+			
Number Facts (L)				+		+		
Arith Tracking (L)						+		
Symbol Arith I (L)						+		
Symbol Arith II (L)		+				+		
Sun-Tue Addition (L)						+		